MASPS for ADS-B Rev. A

Tracking Information (committee secretary only)	
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Short Title for Change Issue:	TCP Types and Parameters to Represent Trajectory Change Segments

MASPS Document Reference:		Originator Information:	
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Section number(s)		Phone	206- 662- 8540 / 206-523-1584
Paragraph number(s)	2.1.2.3.3, 3.4.3.2,3.4.3.3	E-mail	anthony.w.warren@boeing.com
Table/Figure number(s)	3-3(a), 3-6, 3-7 ?	Other	Boeing ATM Services

Proposed Rationale for Consideration (originator should check all that apply):	
	Item needed to support of near-term MASPS/MOPS development
X	DO-260/ED-102 1090 MHz Link MOPS Rev A
X	ASA MASPS
	TIS-B MASPS
X	UAT MOPS
	Item needed to support applications that have well defined concept of operation
	Has complete application description
	Has initial validation via operational test/evaluation
	Has supporting analysis, if candidate stressing application
	Item needed for harmonization with international requirements
X	Item identified during recent ADS-B development activities and operational evaluations
X	MASPS clarifications and correction item
	Validation/modification of questioned MASPS requirement item
	Military use provision item
X	New requirement item (must be associated with traffic surveillance to support ASAS)

Nature of Issue:		Editorial		Clarity		Performance		Functional

Issue Description:

1. Need to clarify scope of TCP intent, i.e. are all planned changes in trajectory routing, vertical path and speed represented by TCP's or are TCP's only required for first order changes in path routing, and changes in climb, descent, level-off status?

2. Need to specify trajectory change type for each TCP to indicate flight segment change / type , e.g. fly-by turn transition, initiate climb segment, end climb segment (level-off). Without TCP type indicators, it may not be possible to unambiguously define or construct a predicted path segment to the TCP point, e.g. the start of turn for a Fly-By TCP is quite different than for a Fly-Over TCP. Similarly, TCP parameters could potentially be fixed, known values, dynamically estimated values, or path restrictions. TCP types can be used to clarify this ambiguity, e.g. an altitude restriction versus estimated altitude during a vertical transition.

3. TCP's only define the intended end-states (x,y,z,t) for a current or subsequent flight segment. Need to broadcast or report additional parameters to ADS-B applications which unambiguously define a nominal path segment to the TCP point. This is fundamentally an integrity issue, i.e. misleading information may be conveyed to an application if the transmitted ADS-B intent information is insufficient to construct a unique path in space to the TCP point. (The issue of trajectory path containment for separation assurance is an extension of this issue, which will be covered in a separate issue paper.)

Issue Description (continued):

Originally from Issue Paper 11 (Capt. Hilb):

4. The use of TCP Data Valid Subfield is not well explained. Proposed resolution is to change the MASPS as shown in Attachment A of this Issue Paper. (*Note: This comment is from Capt. Bob Hilb and was originally contained in Issue Paper 11. It was consolidated into this Issue Paper after consensus to do so was reached by the ad hoc group at their meeting held in May, 2001.*)

Originally from Issue Paper 31 (Tony Warren):

5. Current requirements on update rate for TCP's are implicit requirements and are not directly related to the functional requirements for applications using TCP's:
   - "The rate shall be sufficient to ensure continuous positive assessment by the receiving aircraft at least 2 minutes prior to reaching closest point of approach for class A2 equipage (5 minutes… for Class A3)."
   - "For all elements of the MS report, the assembly function shall provide update when received or indicate "no data available" if none is received in the preceding 10 second period."

6. Report rate should be lower for TCP's that are remote in time, e.g. whenever TTG to the TCP is larger than some threshold based on functional requirements for intent data.

7. Most TCP intent data is static or slowly changing until the time to TCP is imminent, or the TCP data changes to reflect new flight plan intent. The reporting rate should reflect this redundancy in most TCP data and not waste transmission bandwidth to update TCP data that is highly redundant.

Originator's proposed resolution:

(1) The Intent Subgroup of WG-4 recommends that the scope of TCP intent be limited for DO242A to specific, well defined flight segment types as discussed below, representing basic horizontal and vertical flight segments which are explicitly defined in current FMS / RNP documents, e.g. DO236A. We also recommend that the scope of TCP intent remain consistent with tactical lookahead times as specified currently, or as needed for near term separation assurance applications. We propose to achieve this purpose by specification of Horizontal and Vertical TCP types, such that each flight segment is uniquely specified in ADS-B report formats by
   - The Horizontal and Vertical TCP Segment Change Type,
   - Parameters defining the Horizontal and Vertical path to the ending TCP, and
   - The end-point TCP.

(2) Initial flight segment TCP change types recommended by the Intent Subgroup include:
   - Horizontal segment changes: Track to a Fix (TF) and Direct to a Fix (DF) straight line transitions, Fly-By, Fly-Over, and Radius to a Fix (RF) turn transition segments,
   - Vertical transition types: Initiate vertical transition (climb/descend), Exit vertical transition (level-off), Continue vertical path, and Altitude Restriction(s) at TCP.

   Additional TCP types may be added as needed for near term applications, or in future MASPS as needed for evolving operational concepts, e.g. airspeed changes for medium term conflict alerting and path deconfliction.

   Additional supporting material is contained in a separate powerpoint file. Which was resented at February 2001 ad hoc meeting as Working Paper **242A-WP-3-02**.

Originally from Issue Paper 11 (Capt. Hilb):

(4) Proposed MASPS changes from item #4 which was consolidated into this Issue Paper from Issue Paper 11 is found as attachment A.

Originator's proposed resolution (continued):

Originally from Issue Paper 31: (Tony Warren)

(5) Proposed resolution is to broadcast TCP and TCP+1 information at a higher rate when the aircraft is within 2.5 minutes TTG to the affected TCP or TCP+1, and at a lower rate for TTG's larger than 2.5 minutes. (The 2.5 minute criterion is based on a nominal time budget for a flight plan deconfliction application. The time budget includes time for pilot assessment of an assumed Deconfliction Advisory, communications to the ground controller or intruder aircraft, and time to apply a moderate maneuver such as a flight level change to resolve the detected conflict prior to closest approach. See the attached material for further details.)

(6) The high rate broadcasts must be sufficient for high probability of reception within a 10 second interval, i.e. 95% reception probability per 10 second interval. The low rate broadcasts are optional for level A2 equipage, and for level A3 equipage must be sufficient to receive at least one broadcast of TCP intent information with 99% probability between 5 minutes TTG and 2.5 minutes TTG to the affected TCP. (For example, this requirement may be achieved with a low rate broadcast of 30 seconds per transmission interval and a reception probability of at least 70% per broadcast.)

(7) The above 2.5 minute criterion is not a requirement for a level A2 system, i.e. the requirement in section 2.1.2.3.3.1 would become "The rate shall be sufficient to ensure continuous positive assessment by the receiving aircraft at least 2 minutes TTG to the current TCP for class A2 equipage. For class A3 equipage, the transmission rate shall be sufficient to ensure continuous positive assessment by the receiving aircraft at least 2.5 minutes TTG to the affected TCP or TCP+1, and to receive at least one reception of TCP information between 2.5 minutes and 5 minutes TTG to the affected TCP."

(8) Major changes in TCP or TCP+1 intent will be signaled by an appropriate indicator in the Mode Status report. Such changes may require modification of the transmission rate in order to assure reception of changed TCP or TCP+1 intent subject to the same requirements in (2) and (3) above.

The intent of this proposal is to emphasize the importance of TCP information within 2.5 minutes of reaching a TCP point, and to de-emphasize the relative value of any remote TCP information more than 5 minutes away from the affected TCP.

Additional supporting material is contained in the following attachment B pages.

Working Group 6 Deliberations:

May 24, 2001: This Issue Paper was discussed by the ad hoc group at their May 2001 meeting. It was agreed to consolidate material from Issue Papers 11 and 31 into this Issue paper. It was also agreed that this IP will be addressed in Revision A.

July 19, 2001: This Issue Paper was discussed several times during the July WG6 meeting. The original consensus of WG6 was that short-term intent would be clarify and more precisely defined in DO-242A, while long-term intent and TCPs would be moved from the document's body into an appendix. This would be done to emphasize that the data sources and uses TCPs and long-term intent are not currently well defined. While guidance material would be provided for where WG6 believes these items will be in the near future, caveats would be included that any forward manufacturer should implement at their own risk. Later in the meeting, however, WG1 representatives joined WG6 via telephone. During this conversation it was agreed NOT to move the material inot an appendix, buit instead to attempt to develop a generic, flexible TCP/Intent requirement structure that would allow for soe use in the near-term, and more detailed use in the future with a minimum change to the defined requirements. WG1 and WG6 agreed to have a joint meeting in August to better resolve this topic.

Working Group 6 Deliberations (continued):

August 15, 2001: At a joint WG1/WG6 meeting held to discuss resolution of TCPs and intent information it was agreed that DO-242A would address these issues in the following ways:

- Short-term intent would be incorporated into a "Target State Report" which would include such data elements as Target Altitude, Target Heading (or Track Angle), Source Indicators (for each), Mode Indicators (for each), Validity (for each).
- Long-Term Intent and planned Trajectory Changes would be broadcast in a "Trajectory Change Report", which would include such data as Latitude, Longitude, Altitude, Time to Go (TTG), TCP Type* (horizontal & vertical), Turn Direction (??), Turn Radius, Track To/From TCP, Mode Indicators* (horizontal & vertical), TCP Validity* (horizontal & vertical).

It was agreed that WG6 would take these agreements and use it as a bais for writing a white paper on how and these topics will be addressed in DO-242A and documented the reasons for these proposed changes.

August 30, 2001: At the August WG6 meeting, Richard Barhydt presented a first rough draft of the white paper on TCP and Intent (242A-WP-7-01). Tony Warren also presented 242A-WP-7-03, which was his critique of the Richard's 1st draft. After much discussion, it was agreed to scope down the initial draft so as not to try to resolve some of the more contentious aspects in these areas. It was also agreed that the white paper will categorize TCP types into three general groupings:

i. Those TCPs types that are well understood and can currently be accommodated in existing aircraft.
ii. Those TCP types that are future provisioning (top of climb, top of decent, fly-by, radius to fix)
iii. Future types of TCPs (window- or RNP-based)

Richard and Tony will produce a second draft of this white paper for review at the September WG6 meeting.

October 26, 2001: At the October WG6 meeting, it was decided to close this Issue Paper and use IP26 to address all TCP and Intent material for revision A of the ADS-B MASPS.

2.1.2.3.2.1 Current Trajectory Change Point

The TCP from the transmitting aircraft is the point in three-dimensional space where the current operational trajectory is planned to change, and estimated remaining flight time to that point. A TCP transmission indicates that the aircraft intends to fly directly, via a great circle route, to that point. The TCP is defined as a five-element vector consisting of the following:

- Latitude (WGS-84)
- Longitude (WGS-84)
- Altitude (pressure altitude or flight level)
- Time to go (TTG) to the indicated point in space
- Validity bit

Note: The Validity bit is used to indicate that the aircraft is flying to the broadcast TCP and will arrive at the time projected. This indication is intended primarily for new aircraft and manufacturers will design automation systems to insure a TBD level of compliance to a TCP before broadcasting this bit.

The TCP required received…

3.4.4 Minimum ADS-B Report Requirements for Equipage Classes

Table 3-6 Mode-status Report Definition

Element #	Contents
1	Participant Address (Section 2.1.2.1.2)
2	Call Sign (Up to 8 Alpha-numeric Characters) (Section 2.1.2.1.1)
3	Participant Category (Section 2.1.2.1.3)
4	Surveillance Support Code(Normal/Default) (note 3)
5	Emergency/Priority Status (Section 2.1.2.3.1)
6	Class Codes (Section 2.1.2.4)
7	TCP Latitude (Section 2.1.2.3.2)
8	TCP Longitude (Section 2.1.2.3.2)
9	TCP Altitude (Baro Alt/FL) (Section 2.1.2.3.2)
10	TCP Validity(Section 2.1.2.3.2)
~~10~~11	TTG (Section 2.1.2.3.2)
~~11~~12	Operational Mode Specific Data
~~12~~13	Flight Mode Specific Data (note 4)
~~13~~14	Time of Applicability (Section 2.1.1.4)
15	ACAS/TCAS Capability Code (Section 2.1.2.5)

Table 3-7 TCP+1 On-Condition Report Definition

Element #	Contents
1	Participant Address (Section 2.1.2.1.2)
2	TCP+1 (Lat.) (Section 2.1.2.3.2)
3	TCP+1(Long.) (Section 2.1.2.3.2)
4	TCP+1 Altitude (Baro/FL) (Section 2.1.2.3.2)
5	TCP+1 TTG (Section 2.1.2.3.2)
6	TCP Validity(Section 2.1.2.3.2)
~~6~~7	Time of Applicability (Section 2.1.1.4)

Attachments for TCP Update Rate Requirements
March 26, 2001
Anthony Warren, Boeing Air Traffic Management

(1) Justification of shift from "closest point of approach" to TTG update criterion

The "closest point of approach (CPA)" criterion is a receiving side criterion, not a transmission side criterion for determining update rate. If the potential conflicting aircraft has a CPA before the TCP point and less than 2 min to CPA, then state vector information is adequate to judge conflict detection without resorting to TCP data. (Several studies show the adequacy of SV data for short lookahead times). If the potential conflicting aircraft has a CPA between 2 min and 5 min lookahead, then there may be some value in using both SV and TCP data to detect conflicts, and avoid false alarms. In this case we want to have transmission of TCP intent within 5 min TTG to the next TCP to assure enhanced conflict detection performance at somewhat longer lookahead times. If the potential conflicting aircraft has a CPA after the TCP point, then the 5 min TTG criterion provides some capability to extend deconfliction to even longer lookahead times, e.g. 10 min lookahead, even if the CPA occurs after the Trajectory Change Point. Thus, we can eliminate the awkward CPA criterion in the current MASPS and replace this criterion with a simpler to implement TTG to TCP criterion.

(2) Justification for high rate requirements, e.g. 95% reception per 10 second period

This requirement is primarily interpreting the current MASPS, e.g. "continuous positive assessment by the receiving aircraft". It is clear from the implicit requirement to deliver report data within 10 seconds, that a high probability of reception is desired for at least one Mode Status report containing TCP data within each 10 second interval, provided that TTG is sufficiently close (2 min for Class A2). We have assumed a value of 95% reception probability since this means that the probability of not receiving TCP data for 20 seconds or more is very low, i.e. >99.75% probability of receiving at least one TCP within a 20 second interval, given that a TCP should be received for intent assessment.

(3) Justification for 2.5 min Threshold Criterion for Low Rate / High Rate Broadcasts

The 2.5 minute criterion for changing from Low Rate to High Rate "continuous positive assessment" is based on the following crude time budget for a typical deconfliction application:

* Time for pilot to decide that a maneuver is necessary, given that a Conflict Detection has occurred and a Deconfliction Advisory is issued: 0.5 minute

* Time for pilot to communicate a maneuver request to a controller (or to the encounter aircraft in autonomous airspace): 0.5 minute

* Time for pilot to apply moderate maneuver to achieve desired separation, e.g. 1000 foot altitude separation: 1.5 minutes

Total time from Issuance of Conflict Advisory to maneuver completion = 2.5 minutes.
(Note: this time budget for intent based deconfliction needs to be validated /approved or revised as appropriate by the CD&R group.)

(4) Justification for Low Rate Criterion, e.g. one TCP reception for TTG >2.5 min

The TCP Intent data is mostly redundant except for TTG, which changes dynamically on each intent broadcast. There are situations where TCP intent can change dramatically, e.g. insertion of a new turn point or deletion of TCP values when a “Direct To” is used to bypass intermediate waypoints. In such cases, the Mode Status report should flag that some aspect of intent other than TTG has changed and previous Intent values may be invalid. However, in most cases Intent values such as latitudes and longitudes will not change at all or will change gradually over time such as a Top-of-Descent TCP point. Consequently, a low rate criterion is proposed such that for redundant intent data, only one reception in the interval from TTG < 5 min to TTG< 2.5 min is required. Only a major change in intent signaled by the Mode Status report should require a higher update rate in order to avoid using old, possibly invalid intent data. In this case, the update rate criterion should assure that at least one reception of changed TCP information is received for TTG>2.5 min, or the high update rate used, as appropriate.